(54) **Linear polyethylene stretch/shrink films**

(57) A multi-layered thermoplastic polyolefin film having an improved combination of physical characteristics, in particular, an improved combination of elongation, elastic memory, tear resistance and heat shrinkability comprises a first interior layer comprising a low density polyethylene homopolymer and/or a copolymer or ethylene and vinyl acetate; at least one other interior layer comprising a linear low density polyethylene; and two surface layers comprising a copolymer of ethylene and vinyl acetate. Preferred five layer embodiments of the film comprise (1) a core layer of either a low density polyethylene homopolymer or an ethylene viny acetate copolymer or a blend of an ethylene vinyl acetate copolymer with a linear low density polyethylene; (2) two adjacent intermediate layers of a linear low density polyethylene and (3) two surface layers of an ethylene vinyl acetate copolymer.
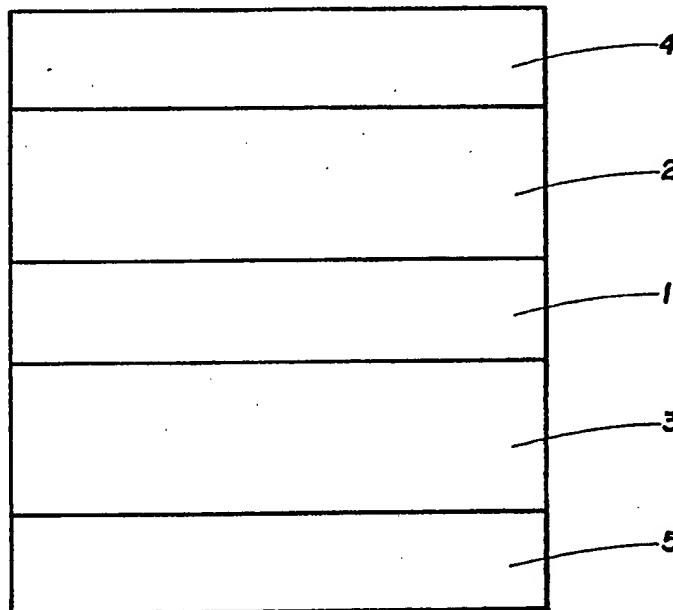
FIG I

GB 2 154 178 A
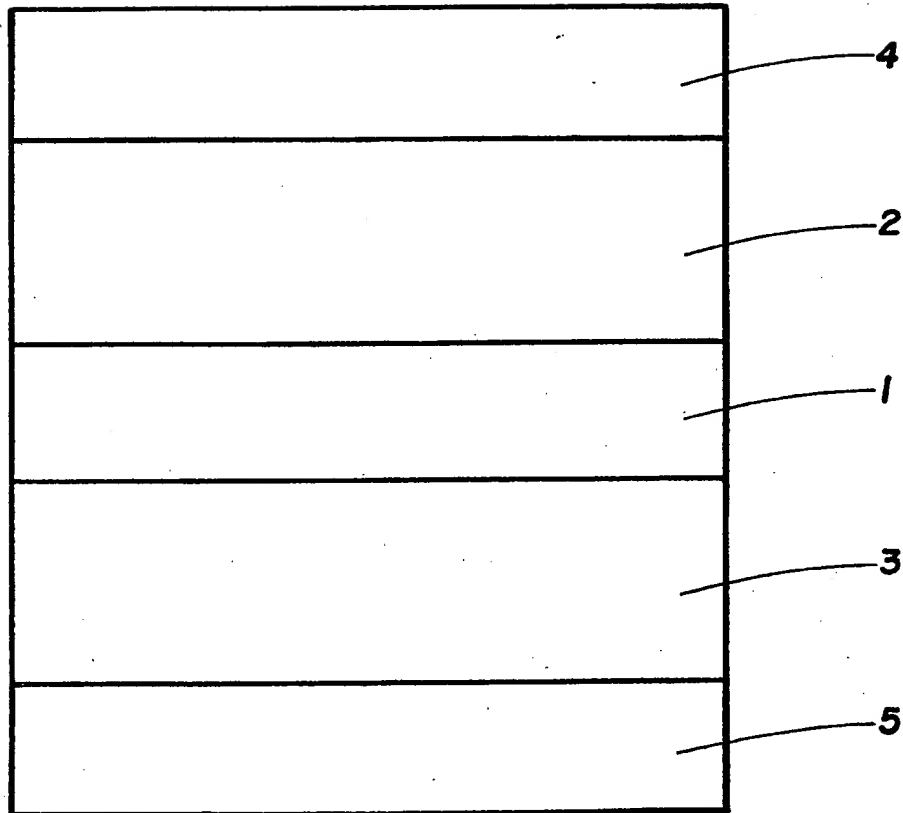
FIG    I

SPECIFICATION

## Linear polyethylene stretch/shrink films

5 The present invention relates to heat shrinkable, thermoplastic packaging film.                                                      5
 The manufacture of shrink films, as is well known in the art, may be generally accompanied by extrusion
(single layer films) or coextrusion (multi-layer films) of thermoplastic resinous materials which have been
heated to their flow or melting point from an extrusion or coextrusion die in, for example, either tubular or
planar (sheet) form. After a post extrusion quenching to cool by, for example, the well-known cascading
10 water method, the relatively thick "tape" extrudate is then reheated to a temperature within its orientation        10
 temperature range and stretched to orient or align the crystallites and/or molecules of the material. The
orientation temperature range for a given material or materials will vary with the different resinous polymers
and/or blends thereof which comprise the material. However, the orientation temperature range for a given
thermoplastic material may generally be stated to be below the crystalline melting point of the material but
15 above the second order transition temperature (sometimes referred to as the glass transition point) thereof.     15
Within this temperature range it is easy to effectively orient the material.
 The terms "orientation" or "oriented" are used herein to generally describe the process step and resultant
product characteristics obtained by stretching and immediately cooling a resinous thermoplastic polymeric
material which has been heated to a temperature within its orientation temperature range so as to revise the
20 inter-molecular configuration of the material by physical alignment of the crystallites and/or molecules of the   20
material to improve certain mechanical properties of the film such as, for example, shrink tension and
orientation release stress. Both of these properties may be measured in accordance with ASTM D 2838-81.
When the stretching force is applied in one direction uniaxial orientation results. When the stretching force is
simultaneously applied in two directions biaxial orientation results. The term oriented is also herein used
25 interchangeably with the term "heat shrinkable" with these terms designating a material which has been          25
stretched and set by cooling while substantially retaining its stretched dimensions. An oriented (i.e. heat
shrinkable) material will tend to return to its original unstretched (unextended) dimensions when heated to
an appropriate elevated temperature.
 Returning to the basic process for manufacturing the film as discussed above, it can be seen that the film,
30 once extruded (or coextruded if it is a multi-layer film) and initially cooled to by, for example, cascading       30
water quenching, is then reheated to within its orientation temperature range and oriented by stretching.
The stretching to orient may be accomplished in many ways such as, for example, by "blown bubble"
techniques or "tenter framing". These processes are well known to those in the art and refer to orientation
procedures whereby the material is stretched in the cross or transverse direction (TD) and/or in the
35 longitudinal or machine direction (MD). After being stretched, the film is quickly quenched while               35
substantially retaining its stretched dimensions to rapidly cool the film and thus set or lock-in the oriented
molecular configuration.
 Of course, if a film having little or no orientation is desired, e.g. non-oriented or non-heat shrinkable film,
the film may be formed from a non-orientable material or, if formed from an orientable material may be "hot
40 blown". In forming a hot blown film the film is not cooled immediately after extrusion or coextrusion but        40
rather is first stretched shortly after extrusion while the film is still at an elevated temperature above the
orientation temperature range of the material. Thereafter, the film is cooled, by well-known methods. Those
of skill in the art are well familiar with this process and the fact that the resulting film has substantially
unoriented characteristics. Other methods for forming unoriented films are well known. Exemplary, is the
45 method of cast extrusion or cast coextrusion which, likewise, is well known to those in the art.              45
 After setting the stretch-oriented molecular configuration the film may then be stored in rolls and utilized
to tightly package a wide variety of items. In this regard, the product to be packaged may first be enclosed in
the heat shrinkable material by heat sealing the shrink film to itself where necessary and appropriate to form
a pouch or bag and then inserting the product therein. If the material was manufactured by "blown bubble"
50 techniques the material may still be in tubular form or it may have been slit and opened up to form a sheet of   50
film material. Alternatively, a sheet of the material may be utilized to over-wrap the product. These
packaging methods are all well known to those of skill in the art. Thereafter, the enclosed product may be
subjected to elevated temperatures by, for example, passing the enclosed product through a hot air or hot
water tunnel. This causes the enclosing film to shrink around the product to produce a tight wrapping that
55 closely conforms to the contour of the product. As stated above, the film sheet or tube may be formed into    55
bags or pouches and thereafter utilized to package a product. In this case, if the film has been formed as a
tube it may be preferable to first slit the tubular film to form a film sheet and thereafter form the sheet into
bags or pouches. Such bag or pouch forming methods, likewise, are well known to those of skill in the art.
 The above general outline for manufacturing of films is not meant to be all inclusive since such processes
60 are well known to those in the art. For example, see U.S. Pat. Nos. 4,274,900; 4,229,241; 4,194,039; 4,188,443;   60
4,048,428; 3,821,182 and 3,022,543. The disclosures of these patents are generally representative of such
processes and are hereby incorporated by reference.
 Alternative methods of producing films of this type are known to those in the art. One well-known
alternative is the method of forming a multi-layer film by an extrusion coating rather than by an extrusion or
65 coextrusion process as was discussed above. In extrusion coating a first tubular layer is extruded and          65

thereafter an additional layer or layers is sequentially coated onto the outer surface of the first tubular layer or a successive layer. Exemplary of this method is U.S. Pat. No. 3,741,253. This patent is generally representative of an extrusion coating process and is hereby incorporated by reference.

Many other process variations for forming films are well known to those in the art. For example, multiple
5 layers may be first coextruded with additional layers thereafter being extrusion coated thereon. Or two            5
multi-layer tubes may be coextruded with one of the tubes thereafter being extrusion coated or laminated onto the other. The extrusion coating method of film formation is preferable to coextruding the entire film when it is desired to subject one or more layers of the film to a treatment which may be harmful to one or more of the other layers. Exemplary of such a situation is a case where it is desired to irradiate one or more
10 layers of a film containing an oxygen barrier layer comprised of one or more copolymers of vinylidene            10
chloride and vinyl chloride. Those of skill in the art generally recognize that irradiation is generally harmful to such oxygen barrier layer compositions. Accordingly, by means of extrusion coating, one may first extrude or coextrude a first layer or layers, subject that layer or layers to irradiation and thereafter extrusion coat the oxygen barrier layer and, for that matter, other layers sequentially onto the outer surface of the extruded
15 previously irradiated tube. This sequence allows for the irradiation cross-linking of the first layer or layers    15
without subjecting the oxygen barrier layer to the harmful effects thereof.

Irradiation of an entire film or a layer or layers thereof may be desired so as to improve the film's resistance to abuse and/or puncture and other physical characteristics. It is generally well known in the art that irradiation of certain film materials results in the cross-linking of the polymeric molecular chains
20 contained therein and that such action generally results in a material having improved abuse resistance.           20
When irradiation is employed to accomplish the cross-linking, it may be accomplished by the use of high energy irradiation using electrons, X-rays, gamma rays, beta rays, etc. Preferably, electrons are employed of at least $10^4$ electron volt energy. The irradiation source can be a Van der Graaff electron accelerator, e.g. one operated, for example, at 2,000,000 volts with a power output of 500 watts. Alternatively, there can be
25 employed other sources of high energy electrons such as the General Electric 2,000,000 volt resonant            25
transformer or the corresponding 1,000,000 volt, 4 kilowatt, resonant transformer. The voltage can be adjusted to appropriate levels which may be, for example, 1,000,000 or 2,000,000 or 3,000,000 or 6,000,000 or higher or lower. Many other apparatus for irradiating films are known to those of skill in the art. The irradiation is usually carried out at between one megarad and 75 megarads, with a preferred range of 8
30 megarads to 20 megarads. Irradiation can be carried out conveniently at room temperature, although higher    30
and lower temperatures, for example, 0°C to 60°C may be employed.

Cross-linking may also be accomplished chemically through utilization of peroxides as is well known to those of skill in the art. A general discussion of cross-linking can be found at pages 331 to 414 of volume 4 of the Encyclopedia of Polymer Science and Technology, Plastics, Resins, Rubbers, Fibers published by John
35 Wiley & Sons, Inc. and copyrighted in 1966. This document has a Library of Congress Catalog Card Number      35
of 64-22188 and the referenced pages are hereby incorporated by reference.

Another possible processing variation is the application of a fine mist of a silicone or anti-fog spray to the interior of the freshly extruded tubular material to improve the further processability of the tubular material. A method and apparatus for accomplishing such internal application is disclosed in copending U.S.
40 Application Serial No. 289,018 filed in the United States Patent & Trademark Office on July 31, 1981. The         40
European patent application counterpart to U.S. application serial no. 289,018 was published on February 9, 1983 under the publication no. of 0071349A2 and is hereby incorporated by reference.

The polyolefin family of shrink films and, in particular, the polyethylene family of shrink films provide a wide range of physical and performance characteristics such as, for example, shrink force (the amount of
45 force that a film exerts per unit area of its cross-section during shrinkage), the degree of free shrink (the        45
reduction in linear dimension in a specified direction that a material undergoes when subjected to elevated temperatures while unrestrained), tensile strength (the highest force that can be applied to a unit area of film before it begins to tear apart), heat sealability, shrink temperature curve (the relationship of shrink to temperature), tear initiation and tear resistance (the force at which a film will begin to tear and continue to
50 tear), optics (gloss, haze and transparency of material), elongation (the degree the film will stretch or           50
elongate at room temperature), elastic memory (the degree a film will return to its original unstretched (unelongated) dimension after having been elongated at room temperature), and dimensional stability (the ability of the film to retain its original dimensions under different types of storage conditions). Film characteristics play an important role in the selection of a particular film and they differ for each type of
55 packaging application and for each type of package. Consideration must be given to the product size, weight,     55
shape, rigidity, number of product components and other packaging materials which may be utilized along with the film material and the type of packaging equipment available.

In view of the many above-discussed physical characteristics which are associated with polyolefin films and films containing a polyolefin constituent and in further view of the numerous applications with which
60 these films have already been associated and those to which they may be applied in the future, it is readily      60
discernable that the need for ever improving any or all of the above described physical characteristics or combinations thereof in these films is great, and, naturally, ongoing. In particular, the quest for a heat shrinkable polyethylene film having an improved combination of elongation, elastic memory, puncture resistance, tear propagation resistance and heat sealability has been ongoing since such a film could
65 compete well in the trayed product (for example, meat such as poultry parts) overwrap market. Historically,      65

polyvinyl chloride (PVC) films have been utilized in this overwrap application because of their good degree of elongation and elastic memory. PVC was superior to conventional heat shrinkable films with regard to overwrapped trayed products which were subject to moisture loss because the PVC was elastic and continued to contract as the product lost moisture and shrank during the distribution cycle. The result was a
5 tight package which was somewhat unattractive because it was leaky. The elasticity of PVC also allowed                                     5
automatic overwrapping machinery to stretch the PVC material about the trayed product during overwrapping of the product and the associated tray. In spite of the fact that the package was leaky, PVC proved superior to conventional heat shrink packages because such conventional packaging materials possessed relatively poor elasticity or elastic memory. Thus, when a product wrapped in such a material
10 shrank from moisture loss during the distribution cycle the film did not also shrink and the result was a loose    10
package having a shopworn appearance.
    Unfortunately, PVC has several drawbacks associated therewith which those in the art wish to improve upon or wholly eliminate. Exemplary of these drawbacks is the fact that PVC tray overwrap film generally evidences both (1) poor seal integrity and (2) poor abuse resistance.
15     The poor seal integrity of PVC overwrap films arises at least in part from the fact that the PVC material in   15
PVC overwrapped trays is tack welded to itself as opposed to being hermetically sealed. Thus, the liquid purge or juices which exude from the overwrapped trayed meat products will leak through a tack sealed PVC overwrapped tray and result in a package that is unsightly and messy from a consumer viewpoint. This drawback appears to be irreconcilably linked to PVC since attempts to hermetically seal PVC in a commercial
20 tray overwrap environment usually result in "burn-through" of the PVC material.                                                     20
    Another major drawback of PVC tray overwrap material is, as stated above, the material's poor resistance to abuse. In this regard the PVC material tends to tear along the edges of the overwrapped tray if rubbed during transit by another tray or an enclosing carton.
    Heat shrinkable polyolefin films having improved abuse resistance are known to those in the art. However,
25 development of the new film of the present invention has led to a satisfactory combination of desired            25
physical characteristics in that the film evidences a new and improved combination of physical characteristics e.g. heat shrinkability, elongation, elastic memory, heat sealability and abuse resistance (puncture resistance and resistance to tear propagation). In particular, past attempts to produce a heat shrinkable polyolefin film which possesses satisfactory elongation and elastic memory have resulted in a
30 film which is deficient in its resistance to tear propagation. That is to say the film has the tendency to tear      30
rapidly or "zipper" once punctured. The "zippering" problem is of great concern since this trait substantially reduces the utility of a film for applications involving automatic packaging equipment. Zippered film results in increased down time.
    The present invention provides a multi-layer stretch/shrink film comprising a first interior layer of a low
35 density polyethylene homopolymer and/or an ethylene vinyl acetate copolymer, at least one other interior      35
layer of a linear low density polyethylene, and two surface layers comprising an ethylene vinyl acetate copolymer.
    This film is particularly useful as a tray overwrap film having advantages over prior art tray overwrap films, and in particular, a new and improved combination of physical characteristics such as, for example, heat
40 shrinkability, puncture and tear resistance, elongation and elastic memory (elasticity). The film also               40
possesses improved resistance to tear propagation, i.e. improved resistance to zippering.
    In a preferred embodiment the new film is a five layer polyolefin film having an interior core layer comprising either a low density polyethylene homopolymer or an ethylene vinyl acetate copolymer or a blend of an ethylene vinyl acetate copolymer with linear low density polyethylene; two adjacent
45 intermediate layers comprising a linear low density polyethylene and two surface layers comprising an          45
ethylene vinyl acetate copolymer.

*Definitions*
    Unless specifically set forth and defined or otherwise limited, the terms "polymer" or '"polymer resin" as
50 used herein generally include, but are not limited to, homopolymers, copolymers, such as, for example        50
block, graft, random and alternating copolymers, terpolymers etc. and blends and modifications thereof. Furthermore, unless otherwise specifically limited the terms "polymer" or "polymer resin" shall include all possible symmetrical structures of the material. These structures include, but are not limited to, isotactic, syndiotactic and random symmetries.
55     The terms "melt flow" as used herein or "melt flow index" is the amount, in grams, of a thermoplastic       55
resin which can be forced through a given orifice under a specified pressure and temperature within ten minutes. The value should be determined in accordance with ASTM D 1238.
    The terms "barrier" or "barrier layer" as used herein means a layer of multi-layer film which comprises a material which acts as a physical barrier to gaseous oxygen molecules. Typically the presence of a barrier
60 layer within a film will reduce the oxygen permeability of the film to less than 70c.c. per square meter, in 24    60
hours, at one atmosphere, 73°F (23°C) and 0% relative humidity. The value should be obtained in accordance with ASTM D 3985-81.
    The terms "surface" or "surface layer" or "skin" or "skin layer" as used herein means a layer of a multi-layer film which comprises a surface thereof.
65     The term "interior" or "interior layer" as used herein refers to a layer of a multi-layer film which is not a   65

skin or surface layer of the film.

The term "core" or "core layer" as used herein refers to an interior layer of a multi-layer film having an odd number of layers wherein the same number of layers is present on either side of the core layer.

The term "intermediate" or "intermediate layer" as used herein refers to an interior layer of a multi-layer
5 film which is positioned between a core layer and a surface layer of said film.

The term polyolefin as used herein refers to polymers of relatively simple olefins such as, for example, ethylene, propylene, butenes, isoprenes and pentenes; including, but not limited to, homopolymers, copolymers, blends and modifications of such relatively simple olefins.

The term "polyethylene" as used herein refers to a family of resins obtained by polymerizing the gas
10 ethylene, $C_2H_4$. By varying the catalysts and methods of polymerization, properties such as density, melt index, crystallinity, degree of branching and cross-linking, molecular weight and molecular weight distribution can be regulated over wide ranges. Further modifications are obtained by copolymerization, chlorination, and compounding additives. Low molecular weight polymers of ethylene are fluids used as lubricants; medium weight polymers are waxes miscible with paraffin; and the high molecular weight
15 polymers (generally over 6,000) are resins generally used in the plastics industry. Polyethylenes having densities ranging from about 0.900 g/cc to about 0.940 g/cc are called low density polyethylenes with those having densities from about 0.941 g/cc to about 0.965 g/cc and over are called high density polyethylenes. The low density types of polyethylenes are usually polymerized at high pressures and temperatures whereas the high density types are usually polymerized at relatively low temperatures and pressures.
20 The term "linear low density polyethylene" (LLDPE) as used herein refers to copolymers of ethylene with one or more comonomers selected from $C_4$ to $C_{10}$ alpha olefins such as butene-1, octene, etc. in which the molecules thereof comprise long chains with few side chains branches or cross-linked structures. The side branching which is present will be short as compared to non-linear polyethylenes. The molecular chains of a linear polymer may be intertwined, but the forces tending to hold the molecules together are physical rather
25 than chemical and thus may be weakened by energy applied in the form of heat. Linear low density polyethylene has a density usually in the range of from about 0.900 g/cc to about 0.940 g/cc and, preferably, the density should be maintained between 0.916 g/cc to 0.928 g/cc for film making purposes. The melt flow index of linear low density polyethylene generally ranges from between about 0.1 to about 10 grams per ten minutes and preferably between from about 0.5 to about 3.0 grams per ten minutes. Linear low density
30 polyethylene resins of this type are commercially available and are manufactured in low pressure vapor phase and liquid phase processes using transition metal catalysts.

The term "ethylene vinyl acetate copolymer" (EVA) as used herein refers to a copolymer formed from ethylene and vinyl acetate monomers wherein the ethylene derived in the copolymer are present in major amounts and the vinyl acetate derived units in the copolymer are present in minor amounts.
35 An "oriented" or "heat shrinkable" material is defined herein as a material which, when heated to an appropriate temperature above room temperature (for example 96°C), will have a free shrink of 5% or greater in at least one linear direction.

All compositional percentages used herein are calculated on a "by weight" basis.

Density should be measured in accordance with ASTM D 1505-68 (reapproved 1979).
40 Free shrink should be measured in accordance with ASTM D 2732.

Shrink tension and orientation release stress should be measured in accordance with ASTM D 2838-81.

The tensile properties of the film should be measured in accordance with ASTM D 882-81.

The elongation properties of the film should be measured in accordance with ASTM D 638.

The haze and luminous transmittance of the film should be measured in accordance with ASTM D 1003-61
45 (reapproved 1971).

The specular gloss of the film should be measured in accordance with ASTM D 2457-70 (reapproved 1977).

The tear propagation of the film should be measured in acordance with ASTM D 1938-67 (reapproved 1978).

The impact resistance of the film should be measured in accordance with ASTM D 3420-80.
50 A "cross-linked" material as used herein shall be defined as a material which after refluxing in boiling toluene or xylene, as appropriate, for forty (40) hours shall have a weight percent residue of at least 5 percent. A procedure for determining whether a material is cross-linked vel non is to reflux 0.4 gram of the material in boiling toluene or another appropriate solvent, for example xylene, for twenty (20) hours. If no insoluble residue (gel) remains the material is determined not to be cross-linked. If after twenty (20) hours of
55 refluxing insoluble residue (gel) remains the material is refluxed under the same conditions for another twenty (20) hours. If more than 5 weight percent of the material remains upon conclusion of the second refluxing the material is considered to be cross-linked. Preferably, at least two replicates are utilized.

The term "crystalline" or "crystalline polymer" material, etc. as used herein refers to a polymeric material which is composed of molecular chains which are so constructed that they can pack together well in ordered
60 arrangements. The finite volume throughout which the order extends is designated by the term "crystallite" with the surrounding disordered regions, if any, being designated by the term "amorphous". The crystallites are denser than the surrounding amorphous regions of the material and also have a higher refractive index. If a crystalline material is oriented the crystallites become generally aligned with each other. Three well known methods for determining the degree of crystallinity are by (1) (a) measuring the specific volume of the
65 specimen (V), (b) measuring the specific volume of the crystallites (Vc) within the specimen and (c)

measuring the specific volume of the amorphous region (Va) contained within the specimen and then utilizing the equation

5        $[\%\,\text{crystallinity} = \dfrac{Va - V}{Va - Vc}]$,                                                                      5

(2) X-ray diffraction methods and (3) infrared absorption methods. All of these methods are well known to those in the art. A general discussion of crystallinity can be found at pages 449 to 527 of volume 4 of the
10 Encyclopedia of Polymer Science and Technology, Plastics, Resins, Rubbers, Fibers published by John Wiley   10
& Sons, Inc. and copyrighted in 1966. This document has a Library of Congress Catalogue Card Number of
64-22188 and the referenced pages are hereby incorporated by reference.
     A rad is the quantity of ionizing radiation that results in the absorption of 100 ergs of energy per gram of a
radiated material, regardless of the source of the radiation. A megarad is $10^6$ rads (MR is an abbreviation for
15 megarad).                                                                             15
     All of the above-identified ASTM standards are hereby incorporated by reference.

*Summary of the invention*
     It has been discovered that a flexible, heat shrinkable thermoplastic packaging film having a desirable
20 combination of physical characteristics such as, heat shrinkability, elongation, puncture resistance, tear       20
resistance, elastic memory and heat shrinkability has been achieved by the multi-layer flexible,
thermoplastic packaging film of the present invention. This multi-layer film comprises a first interior layer of
either a low density polyethylene homopolymer, an ethylene vinyl acetate copolymer or a blend of an
ethylene vinyl acetate copolymer with a linear low density polyethylene. The film also comprises at least one
25 other interior layer comprising a linear low density polyethylene aand two surface layers comprising an        25
ethylene vinyl acetate copolymer. A preferred five layer embodiment has an interior core layer comprised of
either a low density polyethylene homopolymer, an ethylene vinyl acetate copolymer or a blend of an
ethylene vinyl acetate copolymer with a linear low density polyethylene. The preferred five layer film also
comprises two intermediate layers each adjacent to the core layer and each comprising a linear low density
30 polyethylene. Two surface layers comprising an ethylene vinyl acetate copolymer are also present.             30
Preferably, the multi-layer film is both oriented and irradiated. Preferable ranges of irradiation are from 4-8
MR.
     An even more preferred embodiment of the present invention encompasses a five layered film having a
core layer consisting essentially of either a low density polyethylene homopolymer or an ethylene vinyl
35 acetate copolymer or a blend of an ethylene vinyl acetate copolymer with a linear low density polyethylene.   35
This film also has two intermediate layers adjacent to the core layer with each intermediate layer consisting
essentially of a linear low density polyethylene. Two skin layers consisting essentially of a copolymer of
ethylene and vinyl acetate are also present.
     The multi-layer film may be combined with other polymeric materials for specific applications. For
40 instance, additional layers may be added on either or both sides of the film to improve various physical         40
characteristics.

*Brief description of the drawing*
     *Figure I* is a cross-sectional view of a preferred five layered embodiment of the present invention.
45                                                                                       45
*Description of the preferred embodiment*
     Referring to Figure I, which is a cross-sectional view of a five layered preferred embodiment of the present
invention, it is seen that this embodiment comprises a core layer 1, two adjacent intermediate layers 2 and 3
and two skin or surface layers 4 and 5. The preferred thickness ratio of the five layers of 1/1.5/1/1.5/1 is
50 demonstrated in Figure I. Preferred core layer 1 formulations may comprise either (1) an ethylene vinyl         50
acetate copolymer or (2) a blend of ethylene vinyl acetate copolymer with linear low density polyethylene or
(3) a conventional highly branched low density polyethylene.
     Experimentation has revealed that an especially preferred core layer formulation is an ethylene vinyl
acetate copolymer having approximately 3.3% to about 4.1% vinyl acetate derived units in the copolymer.
55 This material may be obtained from the El Paso Polyolefins Company under the trade designation              55
PE204CS95. PE204CS95 is believed to have a density at 23°C of from about 0.9232 gm/cm$^2$ to about 0.9250
gm/cm$^3$ and a flow rate (measured by condition E) of about 2.0 ± 0.5 gm/10 min. Other ethylene vinyl acetate
copolymers or blends of two or more ethylene vinyl acetate copolymers may be utilized to form the core
layer 1. For example an ethylene vinyl acetate copolymer having from about 8.4% to about 9.4% vinyl acetate
60 derived units may be utilized. Such a material may be obtained under the trade designation Elvax 3128 from   60
duPont.
     A preferred linear low density polyethylene may be obtained from the Dow Chemical Company under the
trade designation Dowlex 2045. Dowlex 2045 is believed to have a density of about 0.920 gm/cm$^3$ and a flow
rate (measured by condition E) of from about 0.7 to 1.2 gm/10 min.
65     Returning to Figure I, and in particular, adjacent intermediate layers 2 and 3 it has been determined that a   65

preferred intermediate layer formulation should comprise a linear low density polyethylene material. A preferred linear low density polyethylene is Dowlex 2045. Other linear low density polyethylene materials or blends of two or more linear low density polyethylene materials or blends of two or more linear low density polyethylene materials may be utilized to form the intermediate layers 2 and 3. Preferably the composition of
5  intermediate layers 2 and 3 is the same; however, different linear low density polyethylenes or blends                  5
thereof may be utilized for each intermediate layer.
    With regard to skin layers 4 and 5 it has been determined that a preferred skin layer formulation comprises a copolymer of ethylene and vinyl acetate. The ethylene vinyl acetate copolymer utilized to form the core layer 1 may, preferably, be the same material as that which is utilized to form the two skin or surface layers 4
10  and 5. A particularly preferred skin layer ethylene vinyl acetate copolymer is PE204CS95, described                   10
above.Other ethylene vinyl acetate copolymers or blends of two or more ethylene vinyl acetate copolymers may be utilized to form skin layers 4 and 5. Preferably the composition of skin layers 4 and 5 is the same, however, different ethylene vinyl acetate copolymers or blends thereof may be utilized for each skin layer.
    Those skilled in the art will readily recognize that all of the above disclosed, by weight, percentages are
15  subject to slight variation. Additionally, these percentages may vary slightly as a result of the inclusion or            15
application of additives such as the silicone mist discussed above or agents such as slip and anti-block agents. A preferred anti-block agent is silica which is available from John's Manville under the tradename White Mist. Preferred slip agents are Erucamide (available from Humko Chemical under the tradename Kemamide E), and Stearamide (available from the Humko Chemical Company under the tradename
20  Kemamide S) and N, N−' Dioleoylethylenediamine (available from Glyco Chemical under the tradename              20
Acrawax C). A preferred silicone spray is liquid polyorganosiloxane manufactured by General Electric under the trade designation General Electric SF18 polydimethylsiloxane.
    The general ranges for inclusion or, in the case of the silicone spray, the application of these additives are as follows:
25                                                                                                                        25
        (1) Silica: 250-3000 ppm
        (2) Acrawax C: 200-4000 ppm
        (3) Erucamide: 200-5000 ppm
        (4) Stearamide: 200-5000 ppm
30      (5) Silicone Spray: 0.5 mg.ft$^2$(5.4kg/m$^2$)-and up                                                            30

    When utilized within the specification and claims of the present application the term "consisting essentially of" is not meant to exclude slight percentage variations or additives and agents of this sort.
    Additional layers and/or minor amounts of additives of the types described above may be added to the
35  film structure of the present invention as desired but care must be taken not to adversely affect the desirable          35
physical properties and other characteristics of the inventive film.
    In the preferred process for making the multi-layer film of the present invention the basic steps are coextruding the layers to form a multilayer film, irradiating the film, and then stretching the film to biaxially orient. These steps and additional desirable steps will be explained in detail in the paragraphs which follow.
40     The process begins by blending, if necessary, the raw materials (i.e. polymeric resins) in the proportions           40
and ranges desired as discussed above. The resins are usually purchased from a supplier in pellet form and can be blended in any one of a number of commercially available blenders as is well known in the art. During the blending process any additives and/or agents which are desired to be utilized are also incorporated.
    The resins and applicable additives and/or agents are then fed to the hoppers of extruders which feed a
45  coextrusion die. For the preferred five-layer film having two identical surface layers and two identical               45
intermediate layers at least 3 extruders need to be employed. One for the two skin or surface layers. One for the two intermediate layers and one for the core layer. Additional extruders may be employed if a film having non-identical surface layers or non-identical intermediate layers is desired. The materials are coextruded as a relatively thick tube or "tape" which has an initial diameter dependent upon the diameter of
50  the coextrusion die. The final diameter of the tubular film is dependent upon the racking ratio, e.g. the                50
stretching ratio. Circular coextrusion dies are well known to those in the art and can be purchased from a number of manufacturers. In addition to tubular coextrusion, slot dies could be used to coextrude the material in sheet form. Well known single or multi-layer extrusion coating processes could also be utilized, if desired.
55     An additional process step which should be utilized to manufacture the preferred embodiment of the                  55
presently inventive film is to irradiate the tape or unexpanded tubing or sheet by bombarding it with high-energy electrons from an accelerator to cross-link the materials of the tube. Cross-linking greatly increases the structural strength of the film or the force at which the material can be stretched before tearing apart when the film materials are predominately ethylene such as polyethylene or ethylene vinyl acetate.
60  Irradiation also improves the optical properties of the film and changes the properties of the film at higher             60
temperatures. A preferred irradiation dosage level is in the range of from about 0.5 MR to about 12.0 MR. An even more preferred range is from about 4 MR to about 8 MR. The most preferred dosage level is approximately 5 MR.
    Following coextrusion, quenching to cool and solidify, and irradiation of the tape the extruded tape is
65  reheated and inflated, by application of internal air pressure, into a bubble thereby transforming the narrow            65

tape with thick walls into a wide film with thin walls of the desired film thickness and width. This process is
sometimes referred to as the "trapped bubble technique" of orientation or as "racking". The degree of
inflation and subsequent stretching is often referred to as the "racking ratio" or "stretching ratio". For
example, a transverse racking or stretching ratio of 2.0 would mean that the film had been stretched 2.0
5   times its original extruded size in the transverse direction during transverse racking. After stretching, the          5
tubular film is then collapsed into a superimposed lay-flat configuration and wound into rolls often referred
to as "mill rolls". The racking process orients the film by stretching it transversely and, to some extent,
longitudinally and thus imparts shrink capabilities to the film. Additional longitudinal or machine direction
racking or stretching may be accomplished by revolving the deflate rollers which aid in the collapsing of the
10  "blown bubble" at a greater speed than that of the rollers which serve to transport the reheated "tape" to the          10
racking or blown bubble area. Preferred transverse and longitudinal stretching ratios of the present film
range from about 2.5 transverse by about 3.0 longitudinal to about 5.0 transverse and about 5.0 longitudinal.
A particularly preferred stretching ratio is about 3.5 transverse by about 3.5 longitudinal. All of these
methods of orientation are well known to those of skill in the art.
15      To further disclose and clarify the scope of the present invention to those skilled in the art the following          15
test data are presented.
        Two embodiments of the present invention were formed by coextrusion, irradiated and stretched
(oriented) by application of internal air (bubble technique) in accordance with the teachings described above.
These embodiments are hereinafter designated X and Y. Embodiment X was a five layered film irradiated
20  with approximately 5 MR and had an approximate layer thickness ratio of 1/1/1/1/1. Embodiment X          20
comprised a layer structure of "A/B/about 60%, by weight, C + about 40%, by weight, B/B/A". Embodiment Y
was a five layered film irradiated with approximately 5 MR and had an approximate layer thickness ratio of
1/1.5/1/1.5/1. Embodiment Y comprised a layer structure of "A/B/A/B/A". The properties of these two films
were compared to a three layered stretch/shrink film, hereinafter K, which had demonstrated "zippering".
25  The three layered film had been irradiated with about 5 MR and had an approximate layer thickness ratio of          25
1/2/1. The three layered film (K) comprised a layer structure of "A/B/A". In all of these examples A represents
an ethylene vinyl acetate copolymer having from about 3.3% to about 4.1% vinyl acetate derived units (El
Paso PE 204CS95); B represents a linear low density polyethylene having a density of about 0.920 gm/cm$^3$
(Dowlex 2045) and C represents an ethylene vinyl acetate copolymer having from about 8.4% to about 9.4%
30  vinyl acetate derived units (duPont Elvax 3128).          30
        Previously recorded data with regard to two PVC (polyvinyl-chloride) films is also presented herewith for
comparison with embodiments X and Y. One PVC film was obtained for Goodyear (hereinafter G-PVC).
Whereas the other PVC film was obtained from Filmco under the designation PVC 634. It is believed that this
material was manufactured by the Reynolds Metal Company. This PVC film is hereinafter designated R-PVC.
35                                                                                                                            35

*Zippering test*

        An Omori 2032 stretch wrapper machine was set up to run #8 trays at 40 PPM. Rubber simulated product
was placed in Grace #8 HD trays. A one inch (1" or 2.54 cm) slit was placed either in the transverse or
longitudinal direction of the film one inch below the outside film guiding roller. Product was then placed in
40  the infeed conveyor and overwrapped.          40
        Data was recorded as to whether the one inch (2.54 cm) tear propagated to a point where the film had to be
removed and rethreaded in the machine or whether the tear was able to be fed through the machine and the
result was only a loss of one package. These results are shown below in Table I.

45                                             TABLE I                                                                        45

|       | Longitudinal Slit | | Transverse Slit | |
|-------|---------|-------------------------|---------|-------------------------|
| Film  | No. Run | Continuous Slit Propagation | No. Run | Continuous Slit Propagation |
| X     | 40      | 0                       | 20      | 0                       |
| Y     | 40      | 0                       | 20      | 0                       |
| K     | 40      | 38                      | 20      | 0                       |

55                                                                                                                            55

        The results of Table I disclose that when the three films were slit in the longitudinal direction there was a
significant difference in the amount of tear propagation (zippering) in the control film (K) as compared to the
embodiments of the present invention (X and Y). the control film (K) propagated continuously approximately
60  95% of the time when slit in the longitudinal direction whereas neither film embodiment X or Y ever          60
propagated continuously when slit in the longitudinal direction.
        When testing the three films with transverse slits no significant difference was observed since none of the
three film propagated continuously after having been slit in the transverse direction.
        Table II, below, compares the five products with regard to many differing physical characteristics.

## TABLE II

| | X | | Y | | K | | G-PVC | | R-PVC | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Layer Thickness Ratio** | 1/1/1/1 | | 1/1.5/1/1.5/1 | | 1/2/1 | | — | | — | |

**Tensile At Break And 73°F (23°C)[1]**

| | PSI (100's) | kPa (1000's) | PSI (100's) | kPa (1000's) | PSI (100's) | kPa (1000's) | PSI (100's) | kPa (1000's) | PSI (100's) | kPa (1000's) |
|---|---|---|---|---|---|---|---|---|---|---|
| Av.[2] Long. | 150.7 | 103.9 | 160.5 | 110.7 | 151.0 | 104.1 | 45.3 | 31.2 | — | — |
| Std. Dev. | 3.9 | 2.7 | 8.6 | 5.9 | 8.2 | 5.7 | 1.5 | 1.0 | — | — |
| 95% C.L.[3] | 6.3 | 4.3 | 13.7 | 9.4 | 13.1 | 9.0 | 2.5 | 1.7 | — | — |
| Av. Trans. | 160.9 | 110.9 | 139.7 | 96.3 | 122.6 | 84.6 | 38.7 | 26.7 | — | — |
| Std. Dev. | 21.1 | 14.5 | 3.7 | 2.6 | 19.5 | 13.4 | 2.0 | 1.4 | — | — |
| 95% C.L. | 33.6 | 23.2 | 6.0 | 4.1 | 31.1 | 21.4 | 3.2 | 2.2 | — | — |

**Elongation At Break And 73°F (23°C) (%)[4]**

| | X | Y | K | G-PVC | R-PVC |
|---|---|---|---|---|---|
| Av. Long. | 198 | 206 | 186 | 316 | — |
| Std. Dev. | 8 | 8 | 12 | 23 | — |
| 95% C.L. | 12 | 12 | 20 | 37 | — |
| Av. Trans. | 204 | 204 | 179 | 337 | — |
| Std. Dev. | 13 | 12 | 21 | 28 | — |
| 95% C.L. | 21 | 20 | 34 | 45 | — |

**Modulus At 73°F (23°C)[5]**

| | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) |
|---|---|---|---|---|---|---|---|---|---|---|
| Av. Long. | 20.5 | 141.3 | 21.5 | 148.2 | 25.6 | 176.5 | 22.7 | 156.5 | 8.8 | 60.7 |
| Std. Dev. | 1.9 | 13.1 | 1.3 | 9.0 | 0.6 | 4.1 | 1.0 | 6.9 | 1.6 | 11.0 |
| 95% C.L. | 3.0 | 20.7 | 2.0 | 13.8 | 1.0 | 6.9 | 1.6 | 11.0 | 2.5 | 17.2 |

**Modulus At 73°F (23°C) continued**

| | X | | Y | | K | | G-PVC | | R-PVC | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) | PSI (1000's) | kPa (1000's) |
| Av. Trans. | 21.2 | 146.2 | 19.4 | 133.8 | 24.4 | 168.2 | 23.1 | 159.3 | 9.0 | 62.0 |
| Std. Dev. | 0.7 | 4.8 | 1.3 | 9.0 | 0.5 | 3.4 | 0.3 | 2.1 | 1.9 | 13.1 |
| 95% C.L. | 1.2 | 8.3 | 2.1 | 14.5 | 0.9 | 6.2 | 0.5 | 3.4 | 3.1 | 21.4 |

TABLE II (continued)

| | X | Y | K | G-PVC | R-PVC |
|---|---|---|---|---|---|
| **Tear Propagation At 73°F (23°C) grams)[6]** | | | | | |
| Av. Long. | 11.88 | 10.88 | 5.06 | 10.55 | 7.00 |
| Std. Dev. | 8.11 | 7.25 | 0.80 | 1.37 | 0.75 |
| 95% C.L | 12.90 | 11.53 | 1.27 | 2.18 | 1.19 |
| Av. Trans. | 7.94 | 7.31 | 5.19 | 17.00 | 11.55 |
| Std. Dev. | 3.88 | 2.32 | 2.73 | 0.49 | 0.66 |
| 95% C.L. | 6.17 | 3.69 | 4.34 | 0.78 | 1.05 |
| **Tear Resistance at 73°F (23°C) (Lbs.)[7]** | lbs N | lbs N | lbs N | — | — |
| Av. Long. | 0.40  1.78 | 0.55  2.45 | 0.52  2.31 | — | — |
| Std. Dev. | 0.15  0.67 | 0.07  0.31 | 0.09  0.40 | — | — |
| 95% C.L. | 0.24  1.07 | 0.11  0.49 | 0.14  0.62 | — | — |
| Av. Trans. | 0.55  2.45 | 0.60  2.67 | 0.54  2.40 | — | — |
| Std. Dev. | 0.13  0.58 | 0.14  0.62 | 0.11  0.49 | — | — |
| 95% C.L. | 0.20  0.89 | 0.23  1.02 | 0.17  0.76 | — | — |
| **Ball Burst Impact At 73°F (23°C) 0.50 In. (12.7 mm) Diam. Sphere Hd. (Cm-Kg)[8]** | | | | | |
| Average | 11.5 | 11.5 | 11.5 | — | 8.5 |
| Std. Dev. | 0.6 | 0.6 | 1.0 | — | 0.4 |
| 95% C.L. | 0.9 | 0.9 | 1.6 | — | 0.6 |
| **Optical Properties At 73°F (23°C) Haze (%)[9]** | | | | | |
| Avg. | 0.3 | 0.4 | 0.3 | — | 1.6 |
| Std. Dev | 0.1 | 0.1 | 0.0 | — | 0.1 |
| 95% C.L. | 0.2 | 0.1 | 0.0 | — | 0.2 |
| **T. Trans. (%)[10]** | | | | | |
| Avg. | 92.2 | 92.3 | 92.3 | — | 92.4 |
| Std. Dev | 0.1 | 0.1 | 0.1 | — | 0.1 |
| 95% C.L. | 0.2 | 0.1 | 0.1 | — | 0.1 |
| **Clarity (%)[11]** | | | | | |
| Avg. | 83.1 | 83.4 | 85.8 | — | — |
| Std. Dev | 2.5 | 1.4 | 1.3 | — | — |
| 95% C.L. | 3.9 | 2.2 | 2.0 | — | — |

TABLE II (continued)

| | X | Y | K | G-PVC | R-PVC |
|---|---|---|---|---|---|
| **Gloss (45°)[12]** | | | | | |
| Avg. | 99 | 100 | 100 | — | 92 |
| Std. Dev. | 1 | 1 | 1 | — | 1 |
| 95% C.L. | 2 | 1 | 2 | — | 2 |
| **Percent Elastic Recovery After 15% Elongation At 73°F (23°C)[13]** | | | | | |
| Av. Long. | 94.00 | 94.00 | 92.00 | 94.00 | — |
| Std. Dev. | 0.94 | 0.55 | 1.22 | 0.92 | — |
| 95% C.L. | 1.50 | 0.87 | 1.94 | 1.47 | — |
| Av. Trans. | 91.67 | 90.33 | 91.84 | 92.07 | — |
| Std. Dev | 1.27 | 2.07 | 0.84 | 0.77 | — |
| 95% C.L. | 2.03 | 3.30 | 1.33 | 1.22 | — |
| **Percent Permanent Deformation After 15% Elongation At 73°F (23°C)[14]** | | | | | |
| Av. Long | 6.00 | 6.00 | 8.00 | 5.60 | — |
| Std. Dev | 0.94 | 0.55 | 1.22 | 0.92 | — |
| 95% C.L. | 1.50 | 0.87 | 1.94 | 1.47 | — |
| Av. Trans. | 8.33 | 9.67 | 8.16 | 7.93 | — |
| Std. Dev | 1.27 | 2.07 | 0.84 | 0.77 | — |
| 95% C.L. | 2.03 | 3.30 | 1.33 | 1.22 | — |

**Tensile At 20 In./Min. And 73°F (23°C) (PSI)[15]**

**5% Elongation**

| | X | | Y | | K | | G-PVC | | R-PVC |
|---|---|---|---|---|---|---|---|---|---|
| | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | |
| Av. Long. | 15.7 | 108.2 | 13.9 | 95.8 | 15.2 | 104.8 | 5.8 | 40.0 | — |
| Std. Dev. | 1.5 | 10.3 | 1.1 | 7.6 | 1.6 | 11.0 | 0.2 | 1.4 | — |
| 95% C.L. | 2.4 | 16.5 | 1.8 | 12.4 | 2.6 | 17.9 | 0.3 | 2.1 | — |

**5% Elongation continued**

| | X | | Y | | K | | G-PVC | | R-PVC |
|---|---|---|---|---|---|---|---|---|---|
| | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | |
| Av. Trans. | 15.5 | 106.9 | 11.4 | 78.6 | 13.7 | 94.5 | 5.2 | 35.9 | — |
| Std. Dev. | 2.5 | 17.2 | 2.0 | 13.8 | 1.8 | 12.4 | 0.2 | 1.4 | — |
| 95% C.L. | 3.9 | 26.9 | 3.1 | 21.4 | 2.9 | 20.0 | 0.3 | 2.1 | — |

TABLE II (continued)

| | X | | Y | | K | | G-PVC | | R-PVC |
|---|---|---|---|---|---|---|---|---|---|
| | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | (100's) |
| **10% Elongation** | | | | | | | | | |
| Av. Long. | 25.9 | 178.6 | 25.2 | 173.7 | 27.2 | 187.5 | 8.6 | 59.3 | — |
| Std. Dev | 2.0 | 13.8 | 0.7 | 4.8 | 1.5 | 10.3 | 0.3 | 2.1 | — |
| 95% C.L. | 3.1 | 21.4 | 1.1 | 7.6 | 2.4 | 16.5 | 0.4 | 2.8 | — |
| Av. Trans. | 22.8 | 157.2 | 18.5 | 127.6 | 21.7 | 149.6 | 6.8 | 46.9 | — |
| Std. Dev. | 3.3 | 22.8 | 0.6 | 4.1 | 2.2 | 15.2 | 0.2 | 1.4 | — |
| 95% C.L. | 5.3 | 36.5 | 0.9 | 6.2 | 3.6 | 24.8 | 0.4 | 2.8 | — |
| **15% Elongation** | | | | | | | | | |
| Av. Long. | 32.5 | 224.1 | 32.1 | 221.3 | 31.3 | 215.8 | 10.6 | 73.1 | — |
| Std. Dev. | 1.4 | 9.7 | 1.1 | 7.6 | 1.4 | 9.7 | 0.3 | 2.1 | — |
| 95% C.L. | 2.2 | 15.2 | 1.8 | 12.4 | 2.3 | 15.9 | 0.5 | 3.4 | — |
| Av. Trans. | 27.7 | 191.0 | 22.6 | 155.8 | 25.7 | 177.2 | 8.1 | 55.8 | — |
| Std. Dev. | 3.5 | 24.1 | 0.5 | 3.4 | 3.6 | 24.8 | 0.3 | 2.1 | — |
| 95% C.L. | 5.6 | 38.6 | 0.9 | 6.2 | 5.7 | 39.3 | 0.5 | 2.8 | — |
| **20% Elongation** | | | | | | | | | |
| Av. Long. | 35.8 | 246.8 | 36.1 | 248.9 | 34.5 | 237.9 | 12.4 | 85.5 | — |
| Std. Dev. | 0.8 | 5.5 | 0.8 | 5.5 | 1.2 | 8.3 | 0.3 | 2.1 | — |
| 95% C.L. | 1.3 | 9.0 | 1.3 | 9.0 | 1.9 | 13.1 | 0.6 | 4.1 | — |
| Av. Trans. | 32.6 | 224.8 | 34.5 | 237.9 | 31.1 | 214.4 | 9.2 | 63.4 | — |
| Std. Dev. | 4.7 | 32.4 | 1.6 | 11.0 | 3.2 | 22.1 | 0.4 | 2.8 | — |
| 95% C.L. | 7.5 | 51.7 | 2.6 | 17.9 | 5.1 | 35.2 | 0.6 | 4.1 | — |
| **25% Elongation** | | | | | | | | | |
| Av. Long. | 38.7 | 266.8 | 40.1 | 276.5 | 37.4 | 257.9 | 13.8 | 95.1 | — |
| Std. Dev. | 0.9 | 6.2 | 1.6 | 11.0 | 1.6 | 11.0 | 0.5 | 3.4 | — |
| 95% C.L. | 1.5 | 10.3 | 2.6 | 17.9 | 2.6 | 17.9 | 0.7 | 4.8 | — |
| Av. Trans. | 36.5 | 251.7 | 37.4 | 257.9 | 35.0 | 241.3 | 10.1 | 69.6 | — |
| Std. Dev. | 4.9 | 33.8 | 1.6 | 11.0 | 3.0 | 20.7 | 0.5 | 3.4 | — |
| 95% C.L. | 7.7 | 53.1 | 2.6 | 17.9 | 4.7 | 32.4 | 0.8 | 5.5 | — |

TABLE II (continued)

| | X PSI (100's) | X kPa (100's) | Y PSI (100's) | Y kPa (100's) | K PSI (100's) | K kPa (100's) | G-PVC PSI (100's) | G-PVC kPa (100's) | R-PVC |
|---|---|---|---|---|---|---|---|---|---|
| *Tensile At 50 In./Min. And 73°F (23°C) (PSI)*[16] | | | | | | | | | |
| *5% Elongation* | | | | | | | | | |
| Av. Long. | 12.9 | 88.9 | 12.4 | 85.5 | 12.9 | 88.9 | 4.4 | 30.3 | — |
| Std. Dev. | 1.4 | | 1.6 | | 1.3 | | 0.8 | | — |
| 95% C.L. | 2.3 | | 2.6 | | 2.1 | | 1.2 | | — |
| Av. Trans. | 12.0 | | 10.3 | | 12.4 | | 4.2 | | — |
| Std. Dev. | 1.3 | | 1.1 | | 1.2 | | 0.5 | | — |
| 95% C.L. | 2.1 | | 1.7 | | 1.9 | | 0.8 | | — |
| *10% Elongation* | | | | | | | | | |
| Av. Long. | 23.4 | 161.3 | 22.2 | 153.1 | 23.9 | 164.8 | 7.8 | 53.8 | — |
| Std. Dev. | 1.1 | 7.6 | 1.9 | 13.1 | 1.8 | 12.4 | 0.3 | 2.1 | — |
| 95% | 1.7 | 11.7 | 3.1 | 21.4 | 2.9 | 20.0 | 0.5 | 3.4 | — |
| Av. Trans. | 21.0 | 144.8 | 17.9 | 123.4 | 21.0 | 144.8 | 6.7 | 46.2 | — |
| Std. Dev. | 2.8 | 19.3 | 1.3 | 9.0 | 0.6 | 4.1 | 1.0 | 6.9 | — |
| 95% C.L. | 4.5 | 31.0 | 2.0 | 13.8 | 0.9 | 6.2 | 1.5 | 10.3 | — |
| *15% Elongation* | | | | | | | | | |
| Av. Long. | 31.1 | 214.4 | 29.5 | 203.4 | 30.7 | 211.7 | 10.3 | 71.0 | — |
| Std. Dev. | 2.2 | 15.2 | 1.3 | 9.0 | 1.7 | 11.7 | 0.2 | 1.4 | — |
| 95% C.L. | 3.5 | 24.1 | 2.1 | 14.5 | 2.7 | 18.6 | 0.4 | 2.8 | — |
| Av. Trans. | 25.2 | 173.7 | 22.0 | 151.7 | 26.4 | 182.0 | 8.7 | 60.0 | — |
| Std. Dev. | 2.0 | 13.8 | 1.8 | 12.4 | 0.6 | 4.1 | 0.4 | 2.8 | — |
| 95% C.L. | 3.1 | 21.4 | 2.9 | 20.0 | 1.0 | 6.9 | 0.6 | 4.1 | — |
| *20% Elongation* | | | | | | | | | |
| Av. Long. | 36.5 | 251.7 | 33.6 | 231.7 | 34.1 | 235.1 | 12.4 | 85.5 | — |
| Std. Dev. | 2.5 | 17.2 | 1.7 | 11.7 | 1.8 | 12.4 | 0.3 | 2.1 | — |
| 95% C.L. | 4.0 | 27.6 | 2.7 | 18.6 | 2.8 | 19.3 | 0.4 | 2.8 | — |
| Av. Trans. | 29.0 | 199.9 | 25.6 | 176.5 | 30.6 | 211.0 | 9.9 | 68.3 | — |
| Std. Dev | 2.5 | 17.2 | 2.1 | 14.5 | 1.0 | 6.9 | 0.4 | 2.8 | — |
| 95% C.L. | 3.9 | 26.9 | 3.4 | 23.4 | 1.6 | 11.0 | 0.6 | 4.1 | — |

TABLE II (continued)

| | X | | Y | | K | | G-PVC | | R-PVC | |
|---|---|---|---|---|---|---|---|---|---|---|
| **25% Elongation** | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) | PSI (100's) | kPa (100's) |
| Av. Long. | 40.2 | 277.2 | 36.9 | 254.4 | 36.9 | 254.4 | 14.2 | 97.9 | — | — |
| Std. Dev. | 3.4 | 23.4 | 1.6 | 11.0 | 1.7 | 11.7 | 0.3 | 2.1 | — | — |
| 95% C.L. | 5.4 | 37.2 | 2.5 | 17.2 | 2.7 | 18.6 | 0.5 | 3.4 | — | — |
| Av. Trans. | 32.8 | 236.1 | 29.0 | 199.9 | 35.0 | 241.3 | 11.1 | 76.5 | — | — |
| Std. Dev. | 2.7 | 18.6 | 2.4 | 16.5 | 0.9 | 6.2 | 0.5 | 3.4 | — | — |
| 95% C.L. | 4.4 | 30.3 | 3.9 | 26.9 | 1.4 | 9.7 | 0.7 | 4.8 | — | — |
| **Shrink Properties At 165°F (74°C)** Free Shrink (%)[17] | | | | | | | | | | |
| Av. Long. | 14 | | 15 | | 10 | | — | | — | |
| Std. Dev. | 1 | | 1 | | 2 | | — | | — | |
| 95% C.L. | 1 | | 1 | | 3 | | — | | — | |
| Av. Trans. | 16 | | 14 | | 12 | | — | | — | |
| Std. Dev. | 1 | | 2 | | 1 | | — | | — | |
| 95% C.L. | 1 | | 3 | | 2 | | — | | — | |
| **Shrink Force (lbs; Newtons)[18]** | lbs | N | lbs | N | lbs | N | | | | |
| Av. Long. | 0.233 | 1.04 | 0.284 | 1.26 | 0.190 | 0.845 | — | | — | |
| Std. Dev. | 0.013 | 0.058 | 0.009 | 0.040 | 0.022 | 0.098 | — | | — | |
| 95% C.L. | 0.020 | 0.089 | 0.014 | 0.062 | 0.035 | 0.156 | — | | — | |
| **Shrink Force (lbs.) continued** | lbs | N | lbs | N | lbs | N | | | | |
| Av. Trans. | 0.224 | 1.00 | 0.245 | 1.090 | 0.254 | 1.130 | — | | — | |
| Std. Dev. | 0.011 | 0.049 | 0.008 | 0.036 | 0.015 | 0.067 | — | | — | |
| 95% C.L. | 0.018 | 0.080 | 0.013 | 0.058 | 0.024 | 0.107 | — | | — | |
| **Shrink Tension (PSI)[19]** | PSI | kPa | PSI | kPa | PSI | kPa | | | | |
| Av. Long. | 355 | 2448 | 404 | 2785 | 255 | 1758 | — | | — | |
| Std. Dev. | 28 | 193 | 19 | 131 | 10 | 69 | — | | — | |
| 95% C.L. | 44 | 303 | 30 | 207 | 16 | 110 | — | | — | |
| Av. Trans. | 307 | 2117 | 338 | 2330 | 383 | 2641 | — | | — | |
| Std. Dev. | 26 | 179 | 9 | 62 | 21 | 145 | — | | — | |
| 95% C.L. | 42 | 290 | 15 | 103 | 22 | 228 | — | | — | |

TABLE II (continued)

| | X | Y | K | G-PVC | R-PVC |
|---|---|---|---|---|---|
| **Shrink Properties At 185°F (85°C)** | | | | | |
| Free Shrink (%)[17] | | | | | |
| Av. Long | 23 | 25 | 17 | — | — |
| Std. Dev. | 1 | 1 | 4 | — | — |
| 95% C.L. | 1 | 2 | 6 | — | — |
| Av. Trans. | 29 | 27 | 21 | — | — |
| Std. Dev. | 1 | 2 | 1 | — | — |
| 95% C.L. | 1 | 4 | 2 | — | — |
| **Shrink Force (lbs; Newtons)[18]** | lbs / N | lbs / N | lbs / N | | |
| Av. Long. | 0.295 / 1.31 | 0.313 / 1.39 | 0.171 / 0.761 | — | — |
| Std. Dev. | 0.024 / 0.107 | 0.005 / 0.022 | 0.017 / 0.076 | — | — |
| 95% C.L. | 0.039 / 0.173 | 0.008 / 0.036 | 0.026 / 0.116 | — | — |
| Av. Trans. | 0.270 / 1.20 | 0.306 / 1.36 | 0.300 / 1.33 | — | — |
| Std. Dev. | 0.007 / 0.031 | 0.005 / 0.022 | 0.004 / 0.018 | — | — |
| 95% C.L. | 0.011 / 0.049 | 0.008 / 0.036 | 0.006 / 0.027 | — | — |
| **Shrink Tension (PSI)[19]** | PSI / kPa | PSI / kPa | PSI / kPa | | |
| Av. Long. | 396 / 2730 | 469 / 3234 | 309 / 2130 | — | — |
| Std. Dev. | 52 / 359 | 18 / 124 | 40 / 276 | — | — |
| 95% C.L. | 83 / 572 | 28 / 193 | 63 / 434 | — | — |
| Av. Trans. | 413 / 2848 | 409 / 2820 | 399 / 2751 | — | — |
| Std. Dev. | 13 / 90 | 11 / 76 | 26 / 179 | — | — |
| 95% C.L. | 21 / 145 | 17 / 117 | 41 / 283 | — | — |
| **Shrink Properties At 205°F (96°C)** | | | | | |
| Free Shrink (%)[17] | | | | | |
| Av. Long. | 41 | 43 | 32 | — | — |
| Std. Dev. | 1 | 1 | 3 | — | — |
| 95% C.L. | 2 | 1 | 5 | — | — |
| Av. Trans. | 46 | 43 | 38 | — | — |
| Std. Dev. | 1 | 1 | 2 | — | — |
| 95% C.L. | 2 | 2 | 2 | — | — |
| **Shrink Force (lbs.)[18]** | lbs / N | lbs / N | lbs / N | | |
| Av. Long. | 0.331 / 1.47 | 0.306 / 1.36 | 0.188 / 0.836 | — | — |
| Std. Dev. | 0.024 / 0.107 | 0.026 / 0.116 | 0.005 / 0.022 | — | — |
| 95% C.L. | 0.038 / 0.169 | 0.041 / 0.182 | 0.008 / 0.036 | — | — |
| Av. Trans. | 0.273 / 1.21 | 0.286 / 1.27 | 0.315 / 1.40 | — | — |
| Std. Dev. | 0.005 / 0.022 | 0.009 / 0.040 | 0.021 / 0.093 | — | — |
| 95% C.L. | 0.008 / 0.036 | 0.014 / 0.062 | 0.033 / 0.147 | — | — |

**TABLE II (continued)**

**Shrink Tension (PSI)[19]**

| | X (PSI) | X (kPa) | Y (PSI) | Y (kPa) | K (PSI) | K (kPa) | G-PVC | R-PVC |
|---|---|---|---|---|---|---|---|---|
| Av. Long. | 448 | 3089 | 413 | 2848 | 364 | 2510 | — | — |
| Std. Dev | 29 | 200 | 26 | 179 | 10 | 69 | — | — |
| 95% C.L. | 46 | 317 | 41 | 283 | 16 | 110 | — | — |
| Av. Trans. | 470 | 3241 | 400 | 2758 | 405 | 2792 | — | — |
| Std. Dev. | 11 | 76 | 15 | 103 | 13 | 90 | — | — |
| 95% C.L. | 17 | 117 | 24 | 165 | 21 | 145 | — | — |

**TABLE II (continued)**

| | X | Y | K | G-PVC | *R-PVC (*At 220°F) |
|---|---|---|---|---|---|

**Shrink Properties At 215°F (102°C)**

**Free Shrink[17]**

| | X | Y | K | G-PVC | *R-PVC |
|---|---|---|---|---|---|
| Av. Long | 48 | 48 | 40 | — | 16 |
| Std. Dev. | 1 | 1 | 3 | — | 1 |
| 95% C.L. | 2 | 2 | 5 | — | 2 |
| Av. Trans. | 51 | 49 | 45 | — | 1 |
| Std. Dev | 1 | 1 | 1 | — | 0 |
| 95% C.L. | 1 | 2 | 2 | — | 0 |

**Shrink Force (lbs.)[18]**

| | X (lbs) | X (N) | Y (lbs) | Y (N) | K (lbs) | K (N) | G-PVC | R-PVC (lbs) | R-PVC (N) |
|---|---|---|---|---|---|---|---|---|---|
| Av. Long. | 0.286 | 1.27 | 0.301 | 1.34 | 0.198 | 0.881 | — | 0.019 | 0.085 |
| Std. Dev. | 0.030 | 0.133 | 0.020 | 0.089 | 0.010 | 0.044 | — | 0.006 | 0.027 |
| 95% C.L. | 0.047 | 0.209 | 0.032 | 0.142 | 0.015 | 0.067 | — | 0.010 | 0.044 |
| Av. Trans. | 0.269 | 1.20 | 0.303 | 1.35 | 0.310 | 1.38 | — | 0.000 | 0.000 |
| Std. Dev. | 0.008 | 0.036 | 0.003 | 0.013 | 0.016 | 0.072 | — | 0.000 | 0.000 |
| 95% C.L. | 0.012 | 0.053 | 0.005 | 0.022 | 0.025 | 0.111 | — | 0.000 | 0 |

**Shrink Tension (PSI)[19]**

| | X (PSI) | X (kPa) | Y (PSI) | Y (kPa) | K (PSI) | K (kPa) | G-PVC | R-PVC (PSI) | R-PVC (kPa) |
|---|---|---|---|---|---|---|---|---|---|
| Av. Long | 433 | 2985 | 436 | 3006 | 309 | 2130 | — | 28 | 193 |
| Std. Dev. | 43 | 296 | 21 | 145 | 17 | 117 | — | 10 | 69 |
| 95% C.L. | 68 | 469 | 33 | 228 | 27 | 186 | — | 16 | 110 |
| Av. Trans. | 461 | 3178 | 409 | 2820 | 461 | 3178 | — | 0 | 0 |
| Std. Dev. | 11 | 76 | 13 | 90 | 14 | 97 | — | 0 | 0 |
| 95% C.L. | 17 | 117 | 21 | 145 | 22 | 152 | — | 0 | 0 |

TABLE II (continued)

| | X | Y | K | G-PVC | **R-PVC (**At 240°F) (**At 116°C) |
|---|---|---|---|---|---|
| **Shrink Properties At 225°F (107°C)** | | | | | |
| **Free Shrink (%)[17]** | | | | | |
| Av. Long. | 55 | 56 | 51 | — | 19 |
| Std. Dev. | 1 | 1 | 1 | — | 1 |
| 95% C.L. | 1 | 1 | 2 | — | 2 |
| Av. Trans. | 56 | 54 | 55 | — | 5 |
| Std. Dev. | 1 | 1 | 1 | — | 2 |
| 95% C.L. | 1 | 2 | 2 | — | 3 |
| **Shrink Force (lbs.)[18]** | lbs / N | lbs / N | lbs / N | | lbs / N |
| Av. Long. | 0.268 / 1.19 | 0.280 / 1.25 | 0.205 / 0.912 | — | 0.017 / 0.076 |
| Std. Dev | 0.032 / 0.142 | 0.020 / 0.089 | 0.017 / 0.076 | — | 0.004 / 0.018 |
| 95% C.L. | 0.051 / 0.227 | 0.032 / 0.142 | 0.028 / 0.126 | — | 0.007 / 0.031 |
| Av. Trans. | 0.243 / 1.08 | 0.256 / 1.14 | 0.274 / 1.22 | — | 0.000 / 0 |
| Std. Dev. | 0.009 / 0.040 | 0.003 / 0.013 | 0.009 / 0.04 | — | 0.000 / 0 |
| 95% C.L. | 0.014 / 0.062 | 0.004 / 0.018 | 0.014 / 0.062 | — | 0.000 / 0 |
| **Shrink Tension (PSI)[19]** | PSI / kPa | PSI / kPa | PSI / kPa | | PSI / kPa |
| Av. Long. | 370 / 2551 | 389 / 2682 | 308 / 2124 | — | 25 / 172 |
| Std. Dev. | 31 / 214 | 11 / 76 | 7 / 48 | — | 7 / 48 |
| 95% C.L. | 49 / 338 | 18 / 124 | 12 / 83 | — | 11 / 76 |
| Av. Trans. | 388 / 2675 | 355 / 2448 | 330 / 2275 | — | 0 / 0 |
| Std. Dev. | 32 / 221 | 22 / 152 | 17 / 117 | — | 0 / 0 |
| 95% C.L. | 51 / 352 | 35 / 241 | 27 / 186 | — | 0 / 0 |

The following footnotes apply to Table II.

1. ASTM D882-81
2. All values in Table II are averages obtained from four (4) replicate measurements.
3. C.L. is Confidence Limit - for example, if the reported average value was 10 and the 95% C.L. was 2, then if 100 replicate readings were made, 95 of them would have a value between 8 and 12, inclusive.
4. ASTM D882-81
5. ASTM D882-81
6. ASTM D1938-79
7. ASTM D1004-66 (reapproved 1981)
8. ASTM D3420-80

9. ASTM D1003-61 (reapproved 1977)
10. ASTM D1003-61 (reapproved 1977)
11. ASTM D1746-70 (reapproved 1978)
12. ASTM D2457-70 (reapproved 1977)
13. Proposed ASTM standard 12. 2.11 located at pages 85-89 of Draft of the *Standard Guide for the Selection of Stretch, Shrink, and Net Wrap Materials* dated November 23, 1983.
14. See footnote 13
15. ASTM D882-81
16. ASTM D882-81
17. ASTM D2732-70 (reapproved 1976)
18. ASTM D2838-81 (shrink force = shrink tension × film thickness in mils × 1000)
19. ASTM D2838-81

Review of the tear propagation data reported above reveals that the standard deviation and maximum confidence limit of this value for embodiments X and Y are nearly as high or higher than the average values reported. Similar review of the tear resistance data show little improvement of the measured tear resistance of embodiments X and Y as compared to K. These unexpected results are considered to be low when compared to subjective evaluation. Other attempts to obtain more meaningful data met with similar results. These results are believed to indicate that the mechanism responsible for any measured increase in the tear properties of the films is highly variable at low rates of tear. An attempt to evaluate these materials at higher tear rates by an independent testing facility on an Elmendorf tear tester yielded more consistent results although some degree of variability in the five replicate values read for each film was still evident. These results are reported in Table III below.

TABLE III

ELMENDORF TEAR TEST

*1 Sheet Heavy Instrument*

|  | X | Y | K |
|---|---|---|---|
| Longitudinal Direction | 80 grams | 144 grams | 16 grams |
| Transverse Direction | 40 grams | 144 grams | 16 grams |

The above values are average values obtained from five (5) individual replicate measurements.

A second Elmendorf tear test was conducted internally to determine whether these results were reproducable. These results are reported in Table IV below.

TABLE IV

| Sample | Longitudinal | Transverse |
|---|---|---|
| X | 96 grams | 32 grams |
|  | 64 grams | 32 grams |
|  | 64 grams | 32 grams |
|  | 96 grams | 32 grams |
| X Average | 80 grams | 32 grams |
| Y | 96 grams | 96 grams |
|  | 160 grams | 128 grams |
|  | 160 grams | 160 grams |
|  | 96 grams | 128 grams |
| Y Average | 128 grams | 128 grams |
| K | 32 grams | 0 grams |
|  | 32 grams | 32 grams |
|  | 64 grams | 32 grams |
|  | 32 grams | 32 grams |
| K Average | 40 grams | 24 grams |

When reviewing the data reported in Table IV those skilled in the art should be aware that the readout scale records data in 32 gram increments. Thus, each reading is accurate to a degree of ± (plus or minus) 32 grams. The table IV data was gathered in substantial compliance with ASTM D 1922-67 (reapproved 1978). The sample shape did not conform to that required by the standard in that the sample was rectangle of about
5 3 inches by about 2.5 inches (7.5 × 2.5 cm).    5

CLAIMS

1.  A multiply film comprising: a first interior layer comprising a low density polyethylene homopolymer
10 and/or a copolymer of ethylene and vinyl acetate; at least one other interior layer comprising a linear low    10
density polyethylene; and two surface layers comprising a copolymer of ethylene and vinyl acetate.
2.  A film according to claim 1 having five layers, wherein the said first interior layer is a core layer, and wherein there two of said other interior layers each of which is an intermediate layer adjacent to the said core layer.
15 3.  A film according to claim 2 wherein the core layer consists essentially of a said copolymer of ethylene    15
and vinyl acetate, the two intermediate layers each consist essentially of linear low density polyethylene; and the two surface layers each consist essentially of a said copolymer of ethylene and vinyl acetate.
4.  A film according to claim 1 or 2 wherein the said first interior or core layer further comprises a linear low density polyethylene or a low density polyethylene homopolymer.
20 5.  A film according to claim 4 wherein the said first interior or core layer consists essentially of a blend of    20
about 60%, by weight, of an ethylene vinyl acetate copolymer having from about 8.4% to about 9.4%, by weight, vinyl acetate derived units with about 40%, by weight, of a linear low density polyethylene having a density of about 0.920 grams per cubic centimeter.
6.  A film according to any of claims 1 to 5 wherein the said first interior or core layer and both of the said
25 surface layers all comprise the same ethylene vinyl acetate copolymer.    25
7.  A film according to claim 1 substantially as hereinbefore described.
8.  A film according to any one of claims 1 to 7 which has been cross-linked.
9.  A film according to claim 8 which has been irradiated with from about 4 MR to 8 MR.
10.  A film according to claim 9 which has been irradiated with about 5 MR.